AN ECONOMIC EVALUATION of STARCH USE in the TEXTILE INDUSTRY

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PREFACE

This study was conducted under the general supervision of Marshall E. Miller, Chief of the Market Potentials Branch, Marketing Economics Division, Economic Research Service. It was planned and initiated in collaboration with Dwight L. Miller, Assistant Director, Industrial Development, Northern Utilization Research and Development Division, Agricultural Research Service, and Philip B. Dwoskin, Program Coordinator for Utilization Economics, Marketing Economics Division, Economic Research Service.

Kenneth R. Majors, Federal Extension Service, E. H. Grosse, Group Leader, Textile Laboratory Applications Research, A. E. Staley Manufacturing Company, and E. W. S. Calkins, Economic Research Service, gave consultation and suggestions concerning technical aspects of the study.

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SUMMARY

The demand for starch in textile manufacturing derives from the demand for and supply conditions of the end products of the industry. Roughly 13 percent of the traditional market for textiles was lost over the last two decades to nontextile materials such as paper, plastics, rubber, and glass. Also, domestic consumption of natural fibers decreased in proportion to the amount of manmade fibers in textiles. Cotton contributed almost 80 percent of the total cotton-equivalent pounds of fibers used annually during 1940-44, but only 52 percent during 1960-64.

Traditionally, starch was a major processing agent in sizing warp yarn and in color printing and finishing of fabrics. It lost a portion of the color printing market, due to both the substitution of pigment printing for conventional printing and the substitution of synthetic resins for starch to form the pastes used in conventional printing.

Starch also lost some of its traditional market in finishing fabrics. The increasing use of synthetic fibers initiated a search for more compatible processing agents, resulting in a highly competitive technological development of both materials and processes. Despite the widespread use of the synthetic resins in new finishing processes, considerable amounts of starch are still used to finish some textile fabrics.

Starch's main competitive strength is in warp yarn sizing. About 300 million pounds were used annually for sizing during 1960-64--approximately 80 percent of the total starch used by the textile industry. Starch is not used much for sizing synthetic filament yarn, but it is used for sizing synthetic staple fiber yarns, and staple production has been increasing faster than filament production. Also, it is used widely on blended yarns, which are increasing as a proportion of total textiles and require more size material per weight of fabric. The use of starch for sizing synthetic spun and blended yarns explains why total starch use in textiles increased at about the same rate as the use of all fibers in textile manufacture from the late 1930's to the early 1960's and contradicts the idea that starch is used only for sizing cotton yarn.

Starch waste effluent has been blamed as a source of stream pollution, and synthetic resins have been suggested as substitutes for starch to lessen the stream pollution problem. The laboratory tests used as a basis for comparing the pollution potential of various chemicals have some weaknesses, and there is some question about their reliability when applied to stream conditions. Removing synthetic resins from effluent may cost as much or more than similar treatment for starch. In any case, the cost of starch plus its waste effluent treatment would probably be less than the cost of using synthetic resins for most textile mills.

Starch apparently has a firm economic advantage over the chemical resins for sizing. Recovery and reuse of chemical resins may be a future threat, but it is at present costly.

It is becoming increasingly important that chemicals be "tailor-made" for more specialized tasks in textile sizing, printing, and finishing. The increasing number of different fibers, yarn counts, blends, and fabrics tends to insure, for example, that a sizing agent that performs well for one yarn will not do so for the majority of others. Consequently, starch's economic competitive position will be maintained or improved by the starch industry's ability to provide modified and starch-derived products applicable for sizing the wide variety of yarns and fabrics being woven. Technology is the key to its potential.

AN ECONOMIC EVALUATION OF STARCH USE IN THE TEXTILE INDUSTRY

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INTRODUCTION

Starch has long been used in the manufacture of textile fabrics. Some industry people, however, believe that starch has lost a sizable portion of the textile market during the last two decades and that its use in the industry will decline in the future (11, p. 179 and 25, p. 39). 1/ The purpose of this report is to delineate and evaluate the factors that affect starch use and to appraise its market potential in textile manufacture.

The more direct factors affecting starch use include differences in textile processes (warp sizing, color printing, and finishing), textile fabrics (differentiated both by kind and by weave), and kinds of starch and the synthetic chemicals that may replace starch (including both their price and how well they perform).

Indirect forces also affect starch use. These include new developments in materials and processes; changes in the textile consumer's preference for the end product; changes in knowledge, skill, habit, or preference of mill operators and managers; new designs in machinery and equipment; and legislation or pressures by public governing bodies concerning matters that affect a mill's operations, such as reducing or eliminating stream pollution by the mill.

Data on starch are either scant or nonexistent in many pertinent areas. However, available information does enable an evaluation of the more important factors affecting starch use.

THE CHANGING FIBER MARKET

The demand for starch in textile manufacture derives from the demand and supply conditions for the end products of the industry. A strong demand or favorable supply situation that stimulates sales of a fabric in whose manufacture considerable starch is used will increase the demand for starch. Consequently, the discussion here concerns changes in the market for textiles that are important to starch's future.

1/ Underscored numbers in parentheses refer to items in the Literature Cited, p. 28.

Loss to Nontextile Materials

The textile industry has lost part of its fabric market to nontextile materials such as paper and plastics. This market loss may be estimated by assuming that the end-use market growth kept pace with the population growth--constant per capita consumption. Annual consumption in the traditional end-use market would have required 8,170 million pounds of textiles during the 1960-64 period at the 1940-44 per capita level, (fig. 1). Instead, actual consumption of textiles averaged only 7,099 million pounds annually, an estimated loss to nontextiles of 1,071 million pounds (about 13 percent of the total textile market) within two decades.

The estimate of the market loss to nontextiles is rough but not unrealistic; it depends on the reality of the assumption of constant per capita use of the end products where nontextiles have replaced textiles. Since incomes were increasing, it is likely that per capita use of the end products increased too. However, some of the newer textile materials are lighter, so that weight per article is less. Consequently, the assumption is logically supported on the basis that increasing per capita consumption of end products was compensated by less weight per article.

The estimate also has empirical support. An earlier study (6, p. 12) shows that paper, plastics, rubber, glass, and metal replacement of textile materials in end products increased from 583 million pounds (cotton-equivalent basis) in 1947 to 1,329 million pounds in 1957.

What are the implications for starch? At an average use of 5.28 pounds of starch per 100 pounds of textile fibers consumed domestically the 1,071 million pound loss to nontextiles in the textile market represents a 56-million pound loss for starch in textile manufacture.2/ While it is not known whether starch use in those textiles replaced by nontextiles was more, less, or the same as its average use in all textiles, the data do suggest that starch incurred a sizable market loss.

Cotton's Loss to Manmade Fibers

It is believed that the substitution of textiles that use little or no starch in manufacture for those that use considerable amounts (primarily the replacement of cotton fiber by manmade materials) caused a further decline in starch use.

2/ Data are based on an estimated average annual use of 375 million pounds of starch in textile mills during 1960-64, and 7,099 million pounds of textile fibers consumed. This study concerns only starch use in textile manufacture. The loss as a consequence of nontextiles replacing textiles may be accompanied by an increase of starch used in the manufacture of nontextiles (paper, for example) but is outside the scope of this study.

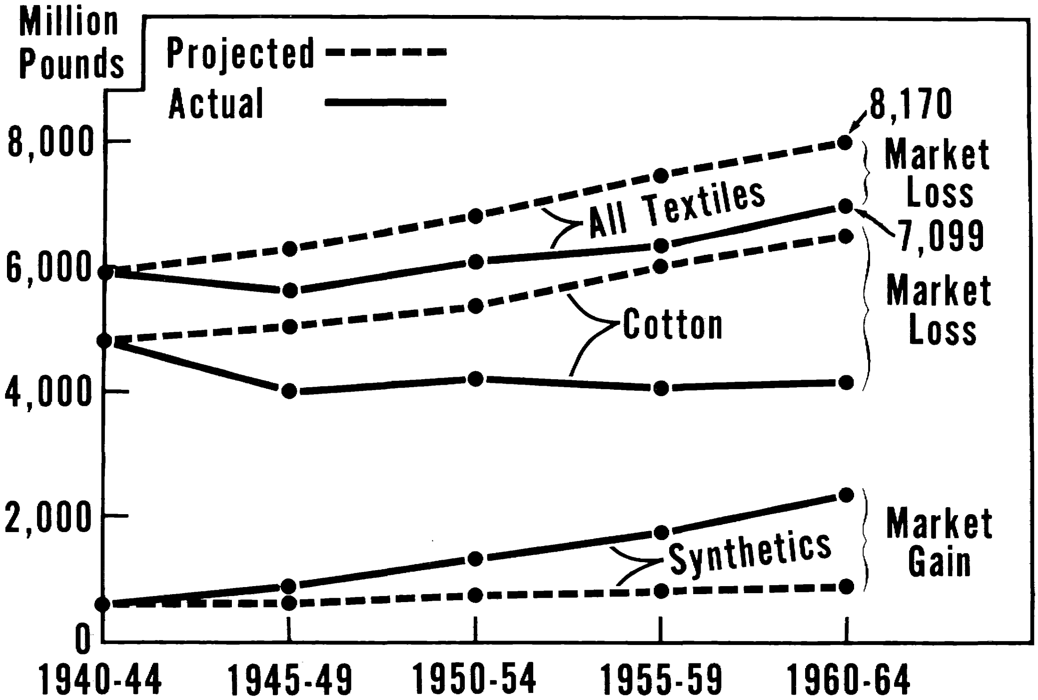

Figure 1.--Change in average annual consumption of all textiles, cotton, and synthetic fibers by 5-year periods, compared with projected consumption based on population growth.

Figure 2 illustrates the trend. Weight in terms of cotton equivalent is used for this purpose since a pound of manmade material replaces more than a pound of cotton for most uses.

Cotton contributed 4,740 million pounds to the average of 5,963 million cotton-equivalent pounds of textiles consumed annually during 1940-44, or almost 80 percent. It contributed only 4,206 million pounds to the average of 8,188 million cotton-equivalent pounds consumed annually during 1960-64, or about 52 percent. If cotton had maintained the same share of the textile market as it had in the early 1940's, it would have contributed 6,509 million pounds to total consumption during 1960-64. Instead, cotton lost about 2.3 billion pounds to other fibers within the last two decades.

If cotton's loss in the textile market reflects adversely on the demand for starch in textile manufacture as believed, the starch industry should indeed be concerned about cotton's future competitive situation. Within the last two decades, cotton lost almost one-third of its total market to non-textile substitutes for textiles and to textile substitutes for cotton. However, whether the shift to manmade fabrics has in fact lowered the demand for starch in textile manufacture is still unresolved. This matter is considered in more detail in the section on sizing warp yarn.

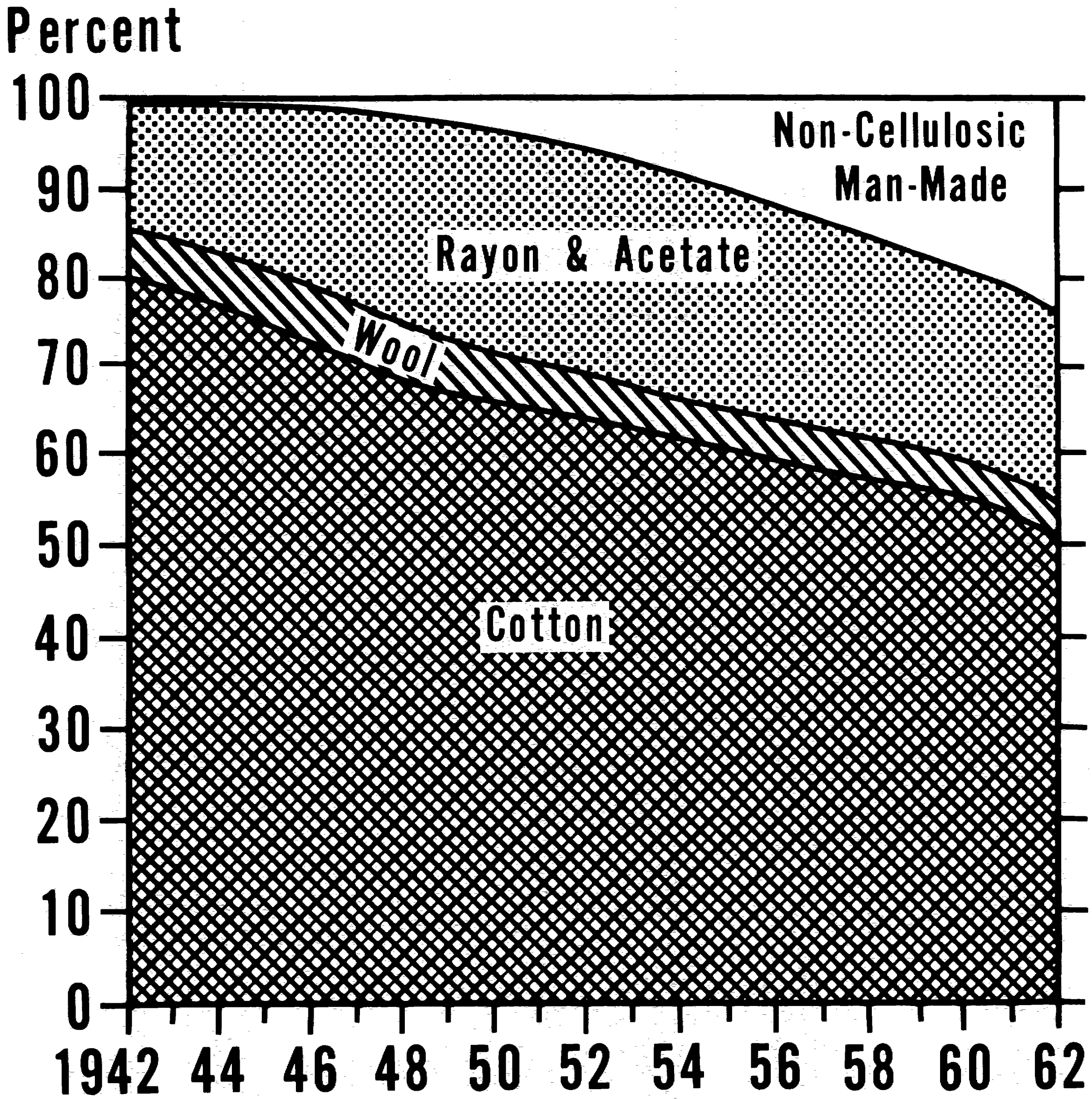

Figure 2.--Proportion by types of the major fibers in total domestic consumption (in cotton equivalent), 5-year moving average, 1940-1964.

GENERAL TRENDS IN STARCH USE

Changes in the textile market that affect the demand for starch are only one dimension of starch's competitive situation. For a decade or more, there has been speculation that substitute chemical compounds were replacing starch in various textile processes. It is believed that starch use has narrowed mainly to sizing cotton warp yarn (11, p. 179). Further, there is concern that synthetic resins, such as carboxymethyl cellulose (CMC) and polyvinyl alcohol (PVA), may replace starch in sizing cotton yarn.

This competitive situation involves the conditions of supply of starch. The starch industry's effectiveness in meeting competition from suppliers of substitute compounds depends on the relative performance of starch and the synthetic resins in textile processes, as well as on relative prices.

It is necessary to first question the more general implications of the notion that starch is being pushed out of textile use. Background on its total industrial use will give perspective to its use in textiles.

The corn wet-milling industry provided slightly more than $2\frac{1}{4}$ billion of the approximately $2\frac{1}{2}$ billion pounds of commercial starch 3/ produced annually in the United States in 1960-64. The industry actually produced an average of more than 5 billion pounds, but converted about 60 percent into sirup, sugar, dextrin, and other products before it was shipped. Data on the corn wet-milling industry should reveal the more important trends in starch use since it furnishes about nine-tenths of total domestic consumption.

Domestic consumption of starch had a healthy growth during 1935-64 (table 1). Growth in domestic shipments for the entire period was 4.5 percent compounded annually. After 1950, it was 2.5 to 3.0 percent.4/

The portion of domestic starch going into industrial uses showed a higher rate of growth--almost 7 percent annually for the whole period and 4 to 5 percent since the early 1950's. This growth, higher than that of the overall economy as measured by the gross national product (GNP), illustrates starch's considerable competitive vigor in industrial uses.

Starch shipments to the textile industry increased during the period, but not as rapidly as total industrial shipments. The major gain in textile starch consumption occurred as the country moved into World War II from the Depression years. The annual growth for the overall period was slightly over 3 percent--less than half the growth of industrial consumption as a whole. It was only 1.4 percent annually during the 1950's and declined to only 0.6 percent in the early 1960's. Even though this is a favorable performance in view of adverse predictions, the growth of starch use in textile manufacture leveled off within the last decade.

In brief, the data show that during 1935-64 industrial use of starch became more important in total domestic starch consumption (increasing from 45 percent to 79 percent) and that textile use of starch, although increasing overall, became less important in total industrial use (declining from 42 percent to 18 percent).

3/ Commercial starch is used here to differentiate that which is sold and shipped as starch from that which is converted to other products by the industry before shipping. The corn wet-milling industry output also includes sorghum grain starch.

4/ Changes of concern to this study are long-term. Growth as used here refers to compound annual rates computed from 5-year averages to reduce annual variations.

Table 1.--Domestic shipments of cornstarch, annual average for 5-year periods, 1935-64

Period	Domestic shipments: Total	Domestic shipments: Industrial: Total 1/	Domestic shipments: Industrial: Textile	Industrial portion of total domestic	Textile portion of total industrial
	Mil. lb.	Mil. lb.	Mil. lb.	Pct.	Pct.
1935-39	725	330	140	45.5	42.4
1940-44	1,168	678	230	58.0	33.9
1945-49	1,281	789	227	61.6	28.8
1950-54	1,662	1,130	286	68.0	25.3
1955-59	1,930	2/ 1,428	306	2/ 74.0	2/ 21.4
1960-64	2,194	3/ 1,733	315	3/ 79.0	3/ 18.2

1/ Nonfood categories in shipments reported by type of industry.
2/ Based on 1955-58 data.
3/ Estimates based on data for 1961

Source: Dun & Bradstreet. Shipments reflect activity of members of Corn Industries Research Foundation.

The increase in cornstarch shipments to textile manufactures was continuing in the early 1960's, although at a low rate (fig. 3). Moreover, the data show that starch use per 100 pounds of cotton consumed by mills increased from slightly over 4 pounds in 1935-39 to about 7.5 pounds in 1960-64. In comparison, its average use per 100 pounds of all fibers consumed by mills remained rather constant at about 4 pounds from 1940 (earliest data available for some synthetics) to 1964 by 5-year averages. This data tends to refute the propositions that starch is used mostly for cotton goods manufacture, that its use there has narrowed primarily to sizing warp yarn in the last decade or so, and that synthetic chemicals are making inroads on its use in sizing cotton yarn. It suggests wider use on all types of yarns.

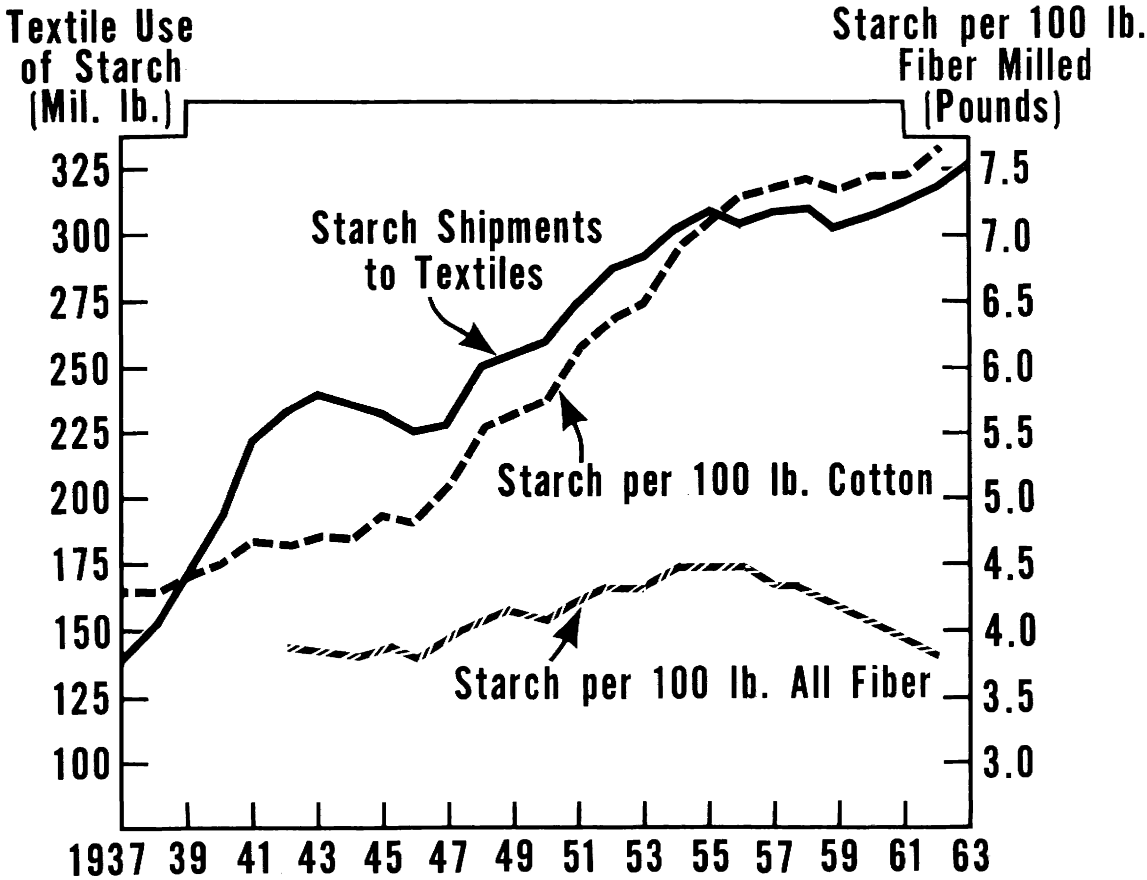

Figure 3.--Starch shipments to textile industry and starch used per 100 pounds of fiber milled, by 5-year moving average, 1937-63.

TEXTILE PROCESSES USING STARCH

Traditionally, starch has had an important role in (1) printing fabrics, (2) finishing fabrics, and (3) sizing warp yarns. Some understanding of its functions, capability, present status, and competitive situation in these three manufacturing processes is necessary to an understanding of its probable future in textiles. Since precise data on its use by process and by type of fabric are not available, we must rely on what information and estimates there are to provide insights on its use.

Background

Of the total starch presently used in textile manufacture, 80 percent or more is used for sizing warp yarns.5/ Most of the remaining 20 percent is used in finishing processes and a smaller part in printing.

Cornstarch shipments6/ to the textile industry averaged about 315 million pounds annually during 1960-64. In addition, 18 to 20 million pounds of dextrin (derived from cornstarch) and 10 to 12 million pounds of wheat starch were used annually. Less is known about the other starches, but potato starch use may have been as much as 20 million pounds and tapioca starch 5 million pounds or more. Small amounts of rice starch, used for specialized purposes, such as silk-screen printing, and sago starch were also consumed.

Thus, textile mills probably averaged about 375 million pounds of starch annually during 1960-64. Corn and grain sorghum starch (including dextrins) contributed about 92 percent to the total.7/ About 300 million of the 375 million pounds were devoted to warp yarn sizing.

Bixler (7) suggested that the following assumptions provide a good estimate of the total market for textile sizing: (1) 75 percent of all cloth is sized; (2) 50 percent of the cloth is warp yarn; and (3) the basic size material requires an average pickup of 15 percent.8/ This method gives an average annual sizing market of 395 million pounds during 1960-64 when applied to the average of 7,036 million pounds of fibers consumed by mills.

Based on these estimates, some 95 million pounds of materials other than starch were required annually for sizing warp yarn during the period. Carboxymethyl cellulose, polyvinvyl alcohol, polyacrylates, and other synthetic polymers are used to size warp yarn, but their use likely did not exceed 15 to 20 million pounds annually during 1960-64. These materials are reported to require less pickup than starch. However, it seems unlikely that materials other than starch would account for the difference between starch use of 300 million pounds estimated earlier and the total warp sizing market of 395 million pounds estimated by Bixler's method.

5/ Trotter's estimate is 75 to 80 percent (22, p. 38). Earlier published estimates were about 75 percent, and the decline of starch used in printing and finishing processes implies a larger proportion of the total used in sizing.

6/ Includes sorghum grain starch.

7/ Some sugars and sirups derived from starch are used in the textile industry. In terms of total starch usage, amounts are not important and a marked expansion in use is not likely. In the early 1960's sirup used in textile manufacture was estimated at about 2 million pounds.

8/ "Pickup" and "add-on" are terms that refer to the amount of starch or size material that adheres to the yarn. The amount is computed on a dry-weight basis and as a percentage of the fiber yarn weight.

Apparently, the disparity resulted from Bixler's overestimation of the market, from the fact that starch used for sizing exceeded the 300-million-pound estimate, or from both factors. In itself, the disparity is neither surprising nor significant, in view of the absence of precise data. However, it does indicate that starch used for sizing warp yarn is unlikely to be less than 80 percent (the earlier estimate) of total starch used for textiles and may be more. Thus, it supports the propositions that starch is losing ground in printing and finishing fabrics and that a greater proportion of its total use in textiles is going to the sizing process.

Dyeing and Printing

Dyeing and printing are the two traditional methods of adding color to fabrics. Dyeing is done on both yarn and piece goods. It produces uniform coloring when yarn or fabric absorbs a solution of coloring material. Printing, on the other hand, applies one or more colors to well-defined areas on fabrics, to form a pattern (dots, flowers, pictures, geometrical designs, etc.).

Further, printing is done by two methods. The conventional method is with dyestuffs of soluble organic compounds which are absorbed by at least the outer layers of the fiber. The other method is by pigment printing with insoluble inorganic substances which are made to adhere to the surface of the fiber. Developments in inorganic pigments and the technology of their use as applied to textile coloring began to spread in the early 1940's.

Starch is used in conventional printing; it is not used in dyeing. In printing with dyestuffs of soluble organic compounds, starch and dextrins are used as thickening agents in the printing pastes. This method of printing was formerly widespread and required large quantities of starch. However, the advent and spread of pigment printing, which uses synthetic resins as film-forming bonding agents, has tended to replace the conventional method of printing. Thus, starch has lost a portion of its printing market (1) by inroads on conventional printing made by pigment printing, and (2) by some substitution of other thickening agents for starch in conventional printing.

An undetermined but apparently small portion of total starch shipments to the textile industry is now used in printing fabrics. There appears to be little basis for expecting that starch use could be significantly expanded in processes for coloring fabrics.

Finishing

Traditionally, starch was the main finishing agent for textile fabrics and garments and was favored with a large market for this purpose. It was used in finishing to add weight, smoothness, and strength to cloth by improving its handle, body, and general appearance. These were the main consumer sales appeal factors before the 1930's. For these purposes, it was comparatively free of competition in price and performance.

The development of rayons, acetates, noncellulosic materials, and various blends set off a search for finishing chemicals that would be more compatible with manmade fabrics than the kinds of starch available at that time. Initial successes apparently revealed even greater potentials, both in materials and processes. The search, once started, was self-perpetuating, and continues today in an increasingly competitive environment.

Starch has lost a sizable portion of the market for textile finishing to the synthetic resins (22, p. 38; 25, p. 39). Its future in finishing does not appear very promising. However, it would be even less promising had the starch industry not recognized the emerging competitive forces. It joined the technology search and developed a wide variety of modified starches and starch-derived materials with better performance for the growing number of specialized textile industry requirements. Consequently, it has held tenaciously to a small part of the finishing market.

Most of starch's loss in textile finishing was not a consequence of failure to perform--or losing to competing substances that better perform--the traditional functions of adding weight, imparting handle, and improving appearance of textiles. The consumer of today demands, and the textile finisher supplies, much more complex cloth characteristics than formerly. The supplier is constantly concerned about new, better, or unique characteristics he may promote to enhance sales of his product. Where weight, handle, and appearance were once sufficient, sales appeal now depends on waterproofing, fireproofing, mildewproofing, wash-and-wear, durable-press, or other finishing innovations. The synthetic resins have better met the requirements for these processes.

Starch's main competitive strength lies in its low initial price, ready availability, and new developments of modified forms for specialized uses. For example, hydroxyethyl starch is said to be adapted for sizing synthetics and other new types of textiles, and can be blended with melamine-formaldehyde and ureaformaldehyde resins for water-resistant finishing (21). Highly converted cornstarch, chlorinated cornstarch, and dextrins are reported as used to perform two principal functions of size in the sanforizing process (26, p. 583). Starch is still used in finishing most work clothing and white goods such as sheets and pillow cases. Although no estimates are available, it is probable that 50 million pounds or more of starch were used annually in finishing during 1960-64.

Sizing Warp Yarns

Starch use in sizing warp yarns is given more attention and emphasis than its use in printing and finishing in this report because (1) most starch shipped to the textile industry is used for sizing, (2) it has more favorably weathered competition in sizing than in the other processes, and (3) its potential is believed to be greater in sizing than in printing and finishing.

Printing and finishing are processes that condition the fabric for sale to the consumer. Their purpose is to improve looks, serviceability, convenience, and other utility and esthetic factors that appeal directly to the consumer and affect his choice of fabrics and apparel and the price he is willing to pay.

Sizing warp yarn, on the other hand, conditions the yarn to better withstand the stress it is subjected to when weaving it into fabric. The sizing material is generally removed from the fabric after weaving and before further processing. Thus, it is a service performed for and used by the manufacturer in production. Consequently, it has no discernible effect on the consumer's choice of fabrics or the price he is willing to pay for them. Cost and performance are the main considerations in the manufacturer's choice of materials for sizing. It is likely that these considerations explain why starch has fared better in sizing than in printing and finishing.

Market Structure for Sizing Materials

To understand starch's competitive position requires some knowledge of yarns, fabric construction, and the function of sizing—also called slashing in the textile trade. These are intricate, complex, and varied in practice so it will be necessary to simplify and generalize the considerations relevant to this study.

Yarns to be used for knitted materials generally are not sized and nonwoven fabrics are manufactured by direct bonding of fibers. Thus, warp sizing is essentially a process used in the manufacture of fabrics woven from yarn.

Weaving involves the interlacing of two sets of yarn at right angles. The warp yarn runs lengthwise in a woven fabric and the filling (or weft) yarn runs back and forth across the width of the fabric. The warp yarn bears the stress and strain of weaving. Its breaking or shedding hinders operation and may produce an inferior cloth. Therefore, the warp yarn is sized to protect it and to improve its weavability. The filling yarn is subjected to little stress in weaving and usually is not sized.

Apparently, some of the higher ply woolen yarns have sufficient strength for weaving and are often not sized. Single-ply woolen and worsted yarns are sized. Plied cotton yarns (such as those used to make duck) are usually not sized.

The warp yarns of other natural and manmade fibers are sized, including both filament and staple of the manmade fibers. Starch is used more widely for sizing manmade fiber yarn than is generally believed. The synthetic yarns require modified forms of starch and more careful selection of additives in the size liquor than is necessary with natural fibers.

The size must have good adhesion and film-forming characteristics, and a wide variety of other properties. Lubricants, softeners, emulsifiers, humectants, preservatives, penetrants, antifoam agents, fillers, and other materials are often added to the size liquor through which the yarn is passed (18, p. 6). The more important ingredients are the film formers, binders, and lubricants or waxes. A warp yarn to be used in print cloth may be sized so that about 15 percent of the warp yarn weight is starch and approximately 10 and 6 percent of the starch weight is binder and wax, respectively (7, p. 28). Since starch is the main material in the size liquor it is referred to as a starch size.

The size function may be better understood if yarn is differentiated into three categories: spun yarns of natural fibers, spun yarns of synthetic fibers, and continuous-filament yarns. All synthetic fibers are produced as continuous filaments initially, but those to be spun will be chopped into short staple lengths similar to the natural fibers. After they are spun into yarn they are referred to as spun or staple fibers to differentiate them from the continuous filament yarn. A yarn comprises a bundle of fibers in a continuous strand.

Spun yarns of natural fibers are strengthened by the spinning twist and the fibers have good cohesion within the yarn bundle. The main concern in sizing spun yarns is to provide a protective coating or film covering the surface of the yarn bundle which will lay the surface fiber ends and fuzz, protect the fibers from abrasion, and prevent shedding during weaving. In contrast, the main concern in sizing filament yarn is that the size material penetrates into the filament bundle and bonds the individual filaments together to prevent them from "ballooning out" or separating from the yarn bundle (8, p. 59; 26, pp. 579-580). A mild size film on the yarn surface is advantageous. Twist strengthens filament yarn also, but imparting it increases the cost of production, and, if highly twisted, it is more limited in use to particular fabric types. Therefore, low-twist filament yarns are preferred.

Spun yarns of synthetic fiber also depend on the spinning twist for strength but, in contrast to spun yarns of natural fiber, have poor fiber-to-fiber cohesion. The individual fiber surface is generally smooth and slippery. Therefore, for spun synthetic yarn, both size penetration to bond individual fibers within the yarn bundle and a surface film coating to lay the surface fiber ends are important.13/

Sizing is essentially an aqueous process. In addition to the different physical characteristics of yarns described above, their water absorption capacity varies. Natural fiber yarns are generally hydrophilic (absorb water readily); synthetic fiber yarns are generally hydrophobic (do not absorb water).

Representative percentages of moisture regain of various fibers at about room temperature and 65 percent relative humidity are as follows (15, p. 120; 16, p. 9; 18, p. 35):

Fiber	Moisture regain (percent)
Wool	16
Viscose rayon	13
Mercerized cotton	11
Silk	11
Cotton	8

13/ If not well bonded, the twist may be disturbed during processing, so that fiber cohesion and yarn strength are reduced.

Fiber	Moisture regain (percent)
Acetates (secondary)	6.5
Nylon	4
Triacetates (primary)	3.5
Orlon	2
Dacron	0.4
Saran	0
Vinyon	0
Dynel	0

Starch performs well on hydrophilic yarns. It does not always achieve good penetration and adhesion in sizing yarn of synthetic materials which do not absorb water.

One authority asserts that "the starch manufacturers have done a creditable job in modifying natural starch, making it a very suitable and acceptable size material for synthetic staple fibers" (8, p. 62). They have not been as effective in developing suitable modifications for sizing the synthetic filament yarns. Exceptions are the use of "amylose" starch as a size for glass fibers and dextrin and starch for sizing rayon filament yarn (7, p. 28; 26, p. 580). Viscose rayon takes up water readily and its fiber characteristics provide a base for adhesion of starch. This is not the case with acetates.

The noncellulosic filament yarns require low concentrations for sizing, are hydrophobic, have a smooth filament surface, and require strong internal bonding (adhesion). This puts starch at a serious disadvantage in sizing synthetic filament yarns. Starch does not satisfactorily adhere to the synthetic substrate and penetrate into the yarn bundle.

Spun synthetic yarns require high concentration of size. Modified starch and starch ethers have been developed that attain satisfactory concentration and viscosity levels and are readily removable from spun yarn. Ease of removing the size material from the woven fabric is another strongly desired characteristic of the size for synthetic yarn since there are no other impurities or foreign materials to be removed. Synthetic resins are usually added to the size liquor as binders to increase adhesion.

Starch adhesion to a 100-percent synthetic substrate is a problem. However, a sizable proportion of the synthetics are blended with natural fibers and regenerated celluloses that are hydrophilic and provide a good adhesion base for starch.

To summarize: Starch is not used significantly in sizing synthetic filament yarns; it is used in modified form and with proper additives in sizing synthetic staple yarns; and it is used more widely in sizing blends of synthetic with natural fiber yarns.

Starch Size Market Trends

An understanding of the demand structure for starch as a sizing material helps explain the increasing starch shipments to textile mills over the last two decades. First, staple has been increasing relative to filament in the fast-growing production of manmade fibers, a trend that favors the use of starch (table 2). Staple is currently about two-fifths of total manmade fiber production.

Also, starch is used widely in sizing many blended yarns, and the blends generally require a high add-on of size. Their production increased considerably in the last decade or more. Blends and mixtures increased from 9.4 to 13.6 as a proportion of total woven fabrics from 1958 to 1962 (table 3). Rayon and acetate blends increased slightly in quantity produced but declined as a proportion of total blend production. Cotton blends increased from 343 million yards in 1958 to 502 million in 1962, but remained about the same as a proportion of total production. Polyester blends increased from 114 million to 437 million yards and from 10.4 to 26.1 percent of total blends and mixtures. There is a growing market for starch in sizing blended yarns if it can maintain its competitive position.

Table 2.--Change in relative proportions of filament and staple in manmade fiber production, 1946-64

Item	Proportion of specified production by periods			
	1946-50	1950-54	1955-59	1960-64
	Percent	Percent	Percent	Percent
Rayon and acetate:				
Filament	77.5	72.6	64.4	56.8
Staple	22.5	27.4	35.6	43.2
Noncellulosic synthetic:				
Filament	88.0	83.0	72.4	68.9
Staple	12.0	17.0	27.6	31.1
Total manmade:				
Filament	78.3	74.4	67.1	62.7
Staple	21.7	25.6	32.9	37.3

Source: (14).

Table 3.--Growth of blends and mixtures in broadwoven fabrics, 1958-1962

Fabric	Unit	Years 1958	1960	1962
Woven fabrics	Mil. yd.	11,629	12,056	12,313
Index (1958 = 100)	Pct.	100.0	103.7	105.9
Blended yarns or mixtures	Mil. yd.	1,095	1,319	1,676
Proportion of total woven	Pct.	9.4	10.9	13.6
1) Rayon or acetate	Mil. yd.	553	543	622
Proportion of total blends	Pct.	50.5	41.2	37.1
2) Cotton	Mil. yd.	343	418	502
Proportion of total blends	Pct.	31.3	31.7	30.0
3) Polyester	Mil. yd.	114	266	437
Proportion of total blends	Pct.	10.4	20.2	26.1

Source: (23).

Appendix table 9 indicates size add-on variation in the 100-percent yarns. Generally, size add-on on filament yarns is one-fourth or less that of their staple counterpart. Bixler (7) does not provide the basis for his "recommended" size agents, which differ somewhat from those in size formulas suggested by Blumenstein (8) in appendix tables 10 and 11. The producer of a triacetate fiber says that "most size formulas for spun triacetate yarns consist of a starch or starch derivative, a softener, and a small amount of an adhesive" and that size add-on is 12 to 15 percent of the weight of the yarn (12). Thus Bixler's 15 to 20 percent "desired" add-on of a "recommended" polyvinvyl alcohol sizing agent conflicts with the general thought that yarns sized with synthetic resins require less add-on than those sized with starch. The desired size add-on varies considerably with the yarn count and characteristics of the fabric into which it will be woven, as well as with the main size agent and other constituents of the size liquor.

The main size agent in the typical formulas for sizing synthetic filament yarns (appendix table 10) presented by Blumenstein (8) are the synthetic resins. However, formulas for synthetic spun yarns (appendix table 11) are generally based on starch with a small amount of polyvinyl alcohol or acrylic binder. The exception is a 100-percent synthetic fabric with a filament warp yarn and a spun filling yarn mixture that would more properly place it in appendix table 10 with filament yarns.

The 100-percent cotton yarns require from less than 10 percent to as much as 15 percent add-on of starch in sizing. Blends generally require higher percentages. The following ranges of size add-on are reasonably comparative figures drawn from suggestions for starch sizing staple yarns in trade literature:

Yarn	Size add-on (percent)
Cotton (100 percent)	10 - 15
Rayon (100 percent)	10 - 12
Rayon-cotton (blend)	12 - 14
Rayon-polyester (blend)	15 - 17
Polyester-cotton (blend)	15 - 22
Polyester-wool (blend)	19 - 23

In summary, the increasing amounts of starch used per 100 pounds of cotton consumed by textile mills in the last two decades is due to (1) the use of starch in sizing spun synthetic fiber yarns and their increase relative to filament yarns, and (2) the use of starch in sizing blended yarns that require relatively large add-ons and the marked increase in blended yarn production. A unit of cotton in a blend requires far more starch for sizing than in a 100 percent cotton yarn. Starch used for sizing is more logically related to all fibers, not cotton alone.

Starch's Competitive Strength

There is no intent to imply that inroads in warp sizing were not made by the synthetic resins in the past, or that they consitute no competitive threat for the future, by the emphasis on starch use in the previous discussion. The focus on starch seemed justified for two reasons: First, both actual and potential inroads by the synthetic resins have been well publicized--possible even overdrawn in terms of existing conditions and economies. Second, the main task was to explain continued increases of starch shipments to the textile industry despite prevalent implications that its use was declining.

Actually, starch has not lost ground to synthetic resins for sizing yarn to a noticeable extent. The main use of the synthetic resins in sizing is on new yarns (some of the filament yarns, for example) for which starch was never a satisfactory size agent. Some use of resin, particularly of carboxymethyl cellulose (CMC) on cotton and cotton blends, is an exception but rather insignificant in terms of the total. Furthermore, a large part of the use of CMC is apparently by one plant, and is a consequence of public pressure regarding a stream pollution problem, (13, p. 162).

Several factors contribute to starch's competitive strength in sizing. Technological improvements were a major force in the last two decades and are likely to be the critical factor in how it maintains its cost advantage and withstands future competition. One starch industry spokesman suggested recently that those in the industry like to think they can tailor-make a product for any application (1, p. 66). However, they have a formidable adversary in the synthetic resin industry which has at least equal flexibility in the potential chemical manipulation of its basic materials.

Starch is cheaper than its synthetic resin competitors. The current price of starch in the forms used for sizing is about 7 to 10 cents per pound delivered. CMC costs about 35 cents, and polyvinyl alcohol is reported to cost about 42 cents per pound. However, the major use of polyvinyl alcohol has been as a binder in starch size formulas.

One cannot safely generalize from published reports the comparative add-on percentages between starch and its potential substitutes. The amount of size add-on varies widely by type and count of yarn, count of fabric, ratio of blends, and slasher practices, among other things. Consequently, the more extreme differences between starch and the synthetic resins quoted in the literature likely refer to different rather than the same sizing tasks. The best information available suggests that the size add-on of CMC may be about two-thirds to three-fourths that of starch for similar sizing tasks. Controlled study is needed to establish more accurately what the add-on values are.

Table 4 illustrates the economic advantage of the initial low price of starch relative to that of CMC at various plant yarn sizing volumes and assuming different add-on values. Savings in the cost of starch compared with that of CMC were computed for CMC add-on ratios of one-half and three-fourths that of starch. However, the absolute level of add-on also affects the savings; i.e., cost savings are larger for a 10-percent CMC and 20-percent starch add-on than for a 7-percent CMC and 14-percent starch add-on even though both are 1 : 2 ratios. Savings for each ratio were computed with starch at 8 and 12 cents per pound to illustrate the effect of changing relative prices, but a large portion of starch shipped to textile mills for sizing is probably at the base price of slightly over 7 cents per pound.

The cost savings when starch is used are quite large. Producers of the synthetic resins claim that greater efficiencies and better performance of their products lessen the cost advantage of starch (13, p. 162). These efficiencies would have to effect considerable cost reduction to equal the savings shown in table 4.

There is some potential cost reduction from eliminating enzyme desizing and increasing loom beam yardage when using the synthetic resins rather than starch for sizing. There is, however, a possibility that cost-increasing factors may cancel out the cost-decreasing features. Shifting from starch to CMC can be quite costly (13, p. 162), especially in the initial period, from mistakes made due to lack of knowledge and experience. Chemical recovery and reuse of synthetic resins may be a potential for reduction of cost; this process apparently is not feasible now, since overhead and process-changing costs are high and outweigh savings.

In brief, there is not sufficient evidence for meaningful comparisons of efficiency costs between starch and the syntehtic resins in sizing. Research studies that provide objective information are sorely needed. Those areas where synthetic resins have sufficiently greater performance and operational efficiencies than starch to offset the cost difference are probably the ones where they are now used. Textile manufacturers feel that starch's competitive status in warp sizing could be enhanced by improved adhesion and better film-forming properties.

Table 4.--Cost savings attributable to differences in add-on and price if starch is used instead of CMC for warp yarn sizing 1/

Million pounds of yarn sized	Add-on		Price per lb.		Saving if starch is used
	CMC	Starch	CMC	Starch	
	Percent	Percent	Cents	Cents	Dollars
1	7	14	35	12	7,700
	7	14	35	8	13,300
	9	12	35	12	17,100
	9	12	35	8	21,900
10	7	14	35	12	77,000
	7	14	35	8	133,000
	9	12	35	12	171,000
	9	12	35	8	219,000
25	7	14	35	12	192,500
	7	14	35	8	332,500
	9	12	35	12	427,500
	9	12	35	8	547,500
50	7	14	35	12	385,000
	7	14	35	8	665,000
	9	12	35	12	855,000
	9	12	35	8	1,095,000

1/ Savings computed here assume all things equal except add-on and price; that is savings are due solely to the price difference at given add-on values. Differences, if any, in efficiencies, performance, and other ingredients of the size liquor may result in cost savings that differ from those shown here.

Quality of performance is probably not as important for sizing yarn as for printing and finishing fabric. Even modest quality differences in printing and finishing can affect consumer appeal (and fabric price) and increase sales. Thus, the synthetic resins can compensate for their relatively high cost in printing and finishing by improving the end product. They do not have this potential in sizing, because the size material is removed long before the fabric reaches the consumer and in no way affects his demand for it. Consequently, the synthetic resins must compete with starch on the basis of cost (and performance as it may affect cost) alone in sizing. Even though they may perform somewhat better, as long as starch does the job, its low cost gives it an advantage.

The forces outlined here lend considerable weight to one comment: "Nothing appears likely to supplant king starch over a wide portion of its (textile) market" (7, p. 29).

STREAM POLLUTION AND STARCH'S COMPETITIVE POSITION

Stream pollution may be defined as the introduction of substances into a stream in quantities sufficient to reduce its usefulness and cause it to become a nuisance. The pollution problem stems from the multiple uses made of our streams and rivers. The increasing population, expanding industrial capacity, and greater wealth of the people have enlarged and intensified the uses made of our streams. Uses include irrigation, municipal water supply, municipal and industrial waste effluent receptacle, fishing, boating, swimming, and sightseeing. Uncontrolled use for some of these purposes creates a nuisance in use for others.

Thus, stream pollution represents a conflict of interest among stream users. There is a growing pressure for more stringent public measures to control industrial and other effluent discharged into streams. That the need has reached critical proportions in some areas is generally recognized, and that controls will be tightened is accepted.

A major concern is industrial waste effluent. Its content, in general, is relatively concentrated in substance compared with municipal sewage and varies widely (1) from one industry to another, (2) from one plant to another in the same industry, and (3) often over time in the same plant. Textile wastes are "as varied in character as the kinds and colors of the goods manufactured" (24, p. 1). Kinds and colors manufactured vary with the season as well. Consequently, it is believed that each plant presents a unique problem in waste disposal.

Discharge of wastes by textile mills pollutes streams in different ways and degrees as illustrated by the following (10, p. 1):

> "Organic matter, such as soaps, grease and oils, depletes the dissolved oxygen in the waterway. Dye or pigment wastes cause unsightly coloration and may also exert a high oxygen demand. Acids, alkalies, and salts of heavy metals are toxic to aquatic life. Structures may be corroded by acids or alkalies discharged to the stream. Insoluble materials may cause unsightly conditions or cut off the food supply of fish by blanketing the stream bottom."

The B.O.D. of textile wastes is the aspect of stream pollution relevant to this study.9/ The reason attention is focused on B.O.D. in textile

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9/ B.O.D. is used in the literature to refer to both biochemical oxygen demand and biological oxygen demand. Generally, laboratory tests measure biochemical oxygen demand. Presumably, this would then be related in some established manner to biological oxygen demand--that which arises in the stream receiving the wastes--in order to predict the latter. There apparently has been no widely accepted standard developed for relating the two.

In this report "laboratory test B.O.D." will be specified when referring to biochemical oxygen demand so that B.O.D. without specification designates biological oxygen demand.

effluent is the belief that its content is significantly affected by whether starch or synthetic resins are used in sizing and other processes. Differences between starch and the synthetic resins in other properties that affect pollution are considered to be neither large nor significant (18, p. 6). However, B.O.D. is a dominant factor in the controversy about the relative competitive strength of starch and the synthetic chemicals in textile operations.

Characteristics of the Problem

Oxygen is dissolved in water and available to support aquatic life in streams. Its source is by absorption from the air and, to a much lesser extent, by transpiration from the plant life present in the water.10/

B.O.D. is defined by J. L. Brown, Jr. (9, p. 79), as the "oxygen required in the decomposition of waste and which will be taken from the water into which the waste is dumped." The more oxygen required during a given period of time, the less will be available to support life in streams. If oxygen is sufficiently depleted, stream life dies. Thus, effluent with high B.O.D. can provoke a serious pollution problem.

The 5-day laboratory test B.O.D. is used as a measure of the relative oxygen depletion potential of substances dumped into streams. Some starches display very high 5-day laboratory test B.O.D., compared with the synthetic resins. Test results have been used as strong justification for "chemical substitution" in textile sizing processes to lower B.O.D. in textile effluent. However, there is evidence of serious weaknesses in the 5-day laboratory test B.O.D. results when used to indicate the relative B.O.D. pollution of streams (17; 19).

Table 5 shows the wide disparity in 5-day laboratory test B.O.D. of starch and synthetic compounds. Some starches have values 20 times higher than CMC and 50 to 60 times higher than polyvinyl alcohol and polyacrylic acid. However, a starch paste, waxy-maize starch (amioca), and a converted starch are shown with 2, 7, and 9 percent 5-day laboratory test B.O.D., respectively--not largely different from those of the synthetic resins.

Table 6 summarizes a series of tests on some synthetic chemicals. The percentage of total theoretical laboratory test B.O.D.11/ satisfied after 5 days varied from 0 for 5 of the 25 chemicals tested to 50 percent for 2 of them. Almost one-third of the chemicals displayed less than 50 percent theoretical laboratory test B.O.D. satisfaction after 20 days.

10/ There is some question about the contribution of plant life. Algae take oxygen from the water when they decompose--possibly as much as they supply while living.

11/ Oxygen which would be required to decompose the compound completely and oxidize the decomposition products completely.

The data in tables 5 and 6 show some weakness in 5-day laboratory test B.O.D. as indicators of stream pollution potentials. The wide disparity between some starches and the synthetic chemicals in 5-day laboratory test B.O.D. may be a consequence of "delayed action" of the latter rather than difference in their absolute level potential. The synthetic chemicals are, in general, less biodegradable. That modified starches are available with a less biodegradable nature, if this is wanted, is indicated by low 5-day laboratory test B.O.D. for some starches in table 5. It is likely that these values were a consequence of slower action since the inherently high oxygen demand of starch on decomposition could hardly be eliminated.

Table 5.—Comparative 5-day laboratory test B.O.D. values of representative starches and chemicals

Chemical	Composition	5-day B.O.D. score
		Percent
Aerotex Resin M-3	Melamine	23
Ambertex M	Starch paste	2
Amioca	Waxy-maize starch	7
B-2 Gum	Starch dextrins	61
Brytex Gum No. 745	Starch	61
Carboxymethyl Cellulose	Cellulose ether	24
Cetosol SF	Synthetic resin	3
Crystal Gum	Converted starch	9
Dextrin	Converted starch	50
Pearl Cornstarch	Starch	50
Rhonite 313	Urea-formaldehyde resin	11
Rhonite 610	Urea-formaldehyde resin	5
Rhonite R-1	Modified urea-formaldehyde resin	7
Elvanol 72-60	Polyvinyl alcohol	1
KD Gum	Starch	57
RTC Gum	Starch-urea	12
Starch No. 450	Starch	46
Tragtex R	Gum tragacanth	2
Wheat Starch	Starch	55
Nicol Starch	Starch	57
Morningstar Starch	Starch	47
Orthocryl 25	Polyacrylic acid	1
Stymer R	Styrene maleic anhydride salt	1

Source: J. W. Masselli, N. W. Masselli, and M. G. Burford (18, pp. 56-57). (Percentage B.O.D. score is based on the weight of the chemical; for example, 50 percent indicates that each pound of chemical will exert 0.5 lb. of laboratory test B.O.D.)

Table 6.--Laboratory test B.O.D. of synthetic organic chemicals

Chemical	Percentage of theoretical B.O.D. satisfied after this number of days incubation at 20° C.						
	5	10	15	20	30	40	50
	Percent						
Monethanolamine	0	58.4	61.2	64.0	66.7	64.0	75.0
Diethanolamine	0.9	1.4	3.5	6.8	--	--	--
Triethanolamine	0	0.8	2.6	6.2	--	--	--
Monoisopropanolamine	5.1	34.0	43.4	46.0	--	--	--
Butylamine	26.5	48.8	50.0	48.8	48.8	48.0	52.3
Morpholine	0.9	0.9	4.0	5.1	--	--	--
Methanol	53.4	62.7	69.4	67.0	69.4	93.4	97.7
Ethanol	44.2	65.4	71.2	71.2	78.9	78.9	77.0
Butanol-2	0	44.2	69.2	72.3	73.2	75.4	77.0
Allyl alcohol	9.1	55.0	78.2	81.8	--	--	--
Ethylene glycol	12.5	51.8	71.0	78.0	--	--	--
Diethylene glycol	1.5	5.6	9.0	18.8	--	--	--
Triethylene glycol	1.4	3.7	11.5	17.0	--	--	--
Propylene glycol	2.2	56.7	72.1	77.8	79.0	77.8	80.0
Butyraldehyde	43.4	59.8	61.5	66.4	64.0	72.2	68.0
Methylisobutyl ketone	4.4	49.3	55.9	56.6	59.6	64.8	64.8
Diethyl ketone	0	12.3	50.8	56.9	--	--	--
Acetone	55.4	71.8	78.2	78.2	--	--	--
Pentanedione-2, 4	5.6	40.0	62.8	69.6	--	--	--
Ethyl acetate	36.0	50.4	51.6	53.8	--	--	--
Butyl acetate	23.5	50.7	46.6	57.4	--	--	--
Isopropyl acetate	12.7	40.0	40.0	40.0	42.7	49.1	--
Carbitol acetate	23.1	44.0	82.4	90.1	94.6	100	--
Butyl Carbitol acetate	13.3	18.4	24.6	67.6	--	--	--
Ethylene chlorhydrin	0	16.1	74.4	88.6	--	--	--

Reproduced from: C. B. Lamb and G. F. Jenkins (17, p. 328).

It is generally claimed that from one-third to three-fourths of a textile mill's total B.O.D. in effluent comes from starch removed in the desizing operation. Table 7 shows data recorded by source of laboratory test B.O.D. in one study. Desizing contributed 45 percent; scouring, 31 percent; and coloring 17 percent of the total. Again, it must be emphasized that 5-day laboratory test B.O.D. may not provide for an adequate solution to stream pollution problems.

Table 7.--Source of laboratory test B.O.D. by cotton manufacturing processes

Process	B.O.D. contribution	B.O.D. source
	Percent	
Desizing	45	Glucose from starch
Scouring	31	Natural waxes, pectins, alcohols, etc. (80%); Penetrants and assistants (20%)
Bleaching	3	Penetrants
Mercerizing	4	Penetrants
Coloring	17	Sodium sulfide, sulfite, acetic acid, etc. (dyeing); starch mainly, plus glycerol, reducing agents, detergents and soap (printing)
Total	100	

Source: J. W. Masselli, N. W. and M. G. Burford (18, p. 55).

The pollution effect of B.O.D. is determined by characteristics of the stream into which the effluent is dumped as well as by the composition of the effluent. Characteristics that affect capability of handling effluent are stream size, depth, rate of flow, and plant life. The larger the stream, the more dispersion is possible for a given effluent and the greater is the amount of oxygen available for use in decomposing waste. The more rapidly flowing streams disperse effluent more widely and increase oxygen replacement capacity. Shallow streams provide greater surface per volume of water for greater oxygen replacement.

The 5-day laboratory test B.O.D. does not seem adequate for directly comparing stream pollution effects of the various sizing chemicals. Among its weaknesses in estimating the effect of organic wastes on streams, the most serious is that "the testing procedure gives only a fraction of the total oxygen demand of the waste and there is no way of knowing the value of this fraction" (19, p. 455). More knowledge is needed about the course of the laboratory test B.O.D. values of starch and the synthetic resins over time. Further, more knowledge is needed relating laboratory test B.O.D., by both total and time factors, to various stream conditions that affect pollution potentials. Under some conditions, the delayed action takeup of oxygen by the less biodegradable synthetic resins may create a greater pollution hazard in waste effluent than starch. Conceivably, the treatment required at the plants also may be more stringent for the synthetic resins. Certainly, research does not appear to support the proposition that substituting the synthetic resins for starch in textile processes, as some groups have advocated, will solve the B.O.D. pollution problem (18, p. 43).

The Alternatives and Their Costs

Research that adequately details the disparity in the type and extent of stream pollution between starch and synthetic resins is lacking. Nevertheless, if the 5-day laboratory test B.O.D. is used as the basis for public action, starch will be at some disadvantage relative to the synthetic materials.

The intense concern about stream pollution that developed in the early 1960's was sparked by public action apparently based on 5-day laboratory test B.O.D. When a major textile mill was ordered to lower the B.O.D. of its effluent, it shifted to CMC to satisfy the order (13, pp. 161-162). The situation was widely publicized, and there was much speculation in the industry about synthetic resins replacing starch in textile sizing. Apparently, the mill satisfied the public authority, at least temporarily, by shifting from starch to CMC. However, the anticipated widespread replacement of synthetic compounds for starch in sizing has not yet occurred.

The company that shifted to CMC posed its problem as either (1) to change to a warp sizing material with much lower B.O.D., or (2) to construct a waste treatment plant. Apparently, these were accepted at that time as realistic alternatives in coping with the pollution problem. There was much discussion but little research on the relative costs of waste treatment versus use of the higher priced synthetic sizing compounds. Most research concentrated on chemical analysis of mill effluent. The results from some of these analyses were coupled with suggestions that "chemical substitution" provided the "most economical" means of handling the B.O.D. problem. However, they did not provide the necessary proof of its validity.

There is a growing feeling that these are not realistic alternatives. Too little is known about the less biodegradable synthetic resins and the pollution problem that may arise from their use. Some believe that all textile plants will sooner or later be required to install effluent treatment systems regardless of the sizing materials they use and that the less biodegradable chemicals may be as costly or more costly to treat.

Some cost data are provided in the literature for a bio-aeration system of effluent treatment developed in the early 1960's. The system was adopted and put to use by a number of mills. The combined investment 12/ and operation cost was reported to be 40 to 50 cents per 100 pounds of starch used in sizing for treating waste from desizing (2, p. 129; 3, pp. 137-39; 5, p. 58; 17; 20, pp. 40-42). Put another way, the costs were 1.0 to 1.3 cents per

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12/ Based on a 10-year amortization of treatment plant construction costs.

pound of B.O.D. removed. The percentage of B.O.D. removed was considered a primary factor of cost in the system, but no data were provided on how its variation affected costs. Capital investment cost, amortized over a 10-year period, was about one-fourth and operating cost about three-fourths of the total annual cost.

The cost of the bio-aeration system of treatment was said to be one-sixth to one-half that of conventional treatment systems. Therefore, desizing waste treatment would vary from less than 1.0 cents per pound of starch used with the bio-aeration system to about 3.5 cents with the older conventional systems.

The amount of effluent treated, size of treatment plant, and other factors affecting costs were not given in the reports. More evidence and detailed information on waste treatment costs are needed. However, the costs above may be realistic, especially for larger operations (4; 9, pp. 78-81), although conditions at individual plants may vary cost considerably.

The available evidence tends to support the proposition that it would be less costly to lower B.O.D. of desizing effluent by treatment plants than shift to the higher priced synthetic sizing materials and assume that no treatment plants would be needed for them. An additional cost as high as 3.5 cents per pound for treatment would give a cost of 10 to 14 cents per pound for using starch, compared with 35 cents for using CMC. Even if sizing required twice as much starch as CMC, it still would be less costly to use starch.

Another view is to consider the size of waste treatment plant investment and operation costs that could be supported by savings (reported in table 4) from using starch rather than CMC for sizing. Assumptions pertinent to savings data reported in table 4 apply to data in table 8 as well. Investment cost was reported as one-fourth and operating cost as three-fourths of total annual cost for the bio-aeration system. Other published estimates indicate the investment cost varies from one-fourth to one-half of total cost of waste treatment plants. Therefore, these proportions were used in computing data in table 8.

For example, with starch 8 cents and CMC 35 cents per pound, savings by using starch were $332,500 to $547,500 for a 25 million pound operation, depending on the relative add-on values of starch and CMC. These savings could support a waste treatment system investment of $831,256 to $1,368,750 (as well as its annual operating costs), if the annual investment costs were one-fourth of total cost. With annual investment one-half of total cost the savings would support investment in a waste treatment system from $1,662,500 to $2,737,500 as well as the annual operating cost.

Further, published estimates of waste treatment costs are considerably less than what the savings would support as shown by comparing savings (column 5) with treatment costs (column 6) in table 8. While savings would support total annual treatment costs from $332,500 to $547,500 for a 25-million-pound operation, the actual treatment costs are estimated at only $17,500 to $105,000, depending on the type of treatment system installed.

Table 8.--Textile waste treatment plant investment and operation cost that could be supported by savings from using starch rather than CMC in sizing yarn 1/

Size of operation and process conditions	Size of investment and operation cost supported by savings: Annual investment 1/4 and operation 3/4 of total cost: Total investment 2/	Annual investment 1/4 and operation 3/4 of total cost: Annual operation cost	Annual investment 1/2 and operation 1/2 of total cost: Total investment 2/	Annual investment 1/2 and operation 1/2 of total cost: Annual operation cost	Savings from using starch	Estimated treatment costs 3/
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
10 million pounds:						
1. 7% CMC and 14% starch add-on	332,500	99,750	665,000	66,500	133,000	7,000 - 49,000
2. 9% CMC and 12% starch add-on	547,500	164,250	1,095,000	109,500	219,000	6,000 - 42,000
25 million pounds:						
1. 7% CMC and 14% starch add-on	831,250	249,375	1,662,500	166,250	332,500	17,500 - 122,500
2. 9% CMC and 12% starch add-on	1,368,750	410,625	2,737,500	273,750	547,500	15,000 - 105,000

1/ Based on savings reported in table 4 and conditions assumed in computing data for table 4 also apply here. All data in this table assume starch price at 8 cents per pound and CMC price at 35 cents per pound.

2/ Investment cost supported assumed a 10-year amortized basis. For example, the $133,000 savings for a 10-million-pound warp yarn sizing operation reported in table 4 (CMC 7% and starch 14% add-on and prices 35 cents and 8 cents per pound, respectively) was divided as follows: 1/4 or $33,250 was taken to support the annual overhead investment and 10 times that was considered the size of the initial lump-sum investment it would support. The remaining $99,750 was left for annual operating expenses.

3/ Lower limits of range computed at .5 cents and higher limits at 3.5 cents per pound of starch used in sizing for annual waste treatment including both overhead and operation cost.

About half the mills using starch for sizing already are served by waste treatment facilities. Most of those that do not have such facilities apparently would construct them rather than shift to higher priced sizing materials (20 p. 40), even should the latter require no treatment. However, there is no assurance that shifting to higher priced sizing materials would eliminate the necessity of a waste treatment plant in the long run. Consequently, the alternative of using higher priced synthetic sizing materials versus using starch with treatment plant and facilities is not a relevant economic alternative for the general conditions that prevail at present.

CONCLUSIONS

Starch probably will maintain about its present quantity level of consumption in textile manufacture. Some growth is possible, but it will be difficult to attain and at a low rate.

Starch's competitive loss to synthetic chemicals over the last decade was probably greatest in fabric printing (as a percentage of the market) and somewhat less so in finishing. The trend is toward such finishes as waterproofing, mildew-proofing, fireproofing, wash-and-wear, and durable press--areas of innovation by the synthetic resins. Starch is apparently used as an additive in some of the new processes, and is still used as the main finishing agent on some fabrics not finished with the new processes. But new finishes are eagerly sought by fabric manufacturers because consumers want them and quickly increase their purchases when they are offered. Consequently, synthetic resin finishing may encroach on the starch-finished fabrics sooner or later. Finishing is an area where the low price of starch does not weigh heavily. Maintaining its present level of use in finishing will require sales effort and improvements that provide starch and modified starch agents for specialized finishing jobs.

Starch apparently has a solid economic competitive advantage in textile warp sizing. The price of the processing materials (rather than enhanced value from results) is the main factor in warp sizing competition. Starch's use in warp sizing is likely to grow, but its future is by no means assured.

Probably the most important consideration for starch competition in warp sizing is performance, which will depend on technological advances. It is in performance that starch will likely maintain its strength or lose the size market. The B.O.D. problem may be an important factor at the competitive margin, but there is increasing concern that stream pollution may be as acute with the synthetic resins as with starch. Chemical recovery and reuse may be a potential threat to starch use in sizing, but considerable research is necessary to lower its cost to compete with the low price advantage that starch enjoys.

The continued growth of starch in warp sizing in recent years was mainly from its use on spun synthetic yarns and on blends. Its use on spun natural fiber yarns furnished a solid base, but 100-percent natural-fiber fabric is decreasing in use. Starch's future use lies mainly in sizing synthetics and synthetic-cotton blends. In this area, its performance is less than desired.

It would be improved by better film-forming properties, improved adhesion, greater flexibility under low-humidity conditions, easy removability, and improved abrasion resistance. Its low price favors starch and if it can maintain or, preferably, improve its performance it is likely to maintain an economic advantage in textile yarn sizing.

The structure of the textile industry has a bearing on the competitive strength of starch and the synthetic resins. The establishments that size the yarn and weave it into cloth are not necessarily the ones that desize it. Should the latter prefer cloth sized with synthetic resins, they may exert pressure on suppliers to do so, without awareness of costs to others and themselves. Under existing conditions, this would likely lead to a higher price for fabrics paid by the consumer.

There are several areas where research that provides more reliable and detailed information is needed. More reliable data on the relative B.O.D. and other stream pollution factors of starch and the synthetic resins and their oxygen use over time under specified test conditions are needed. Research that provides knowledge of their pollution performance under various stream conditions is necessary if test results are to be translated to practical application.

More precise cost data for textile waste treatment are needed. Results should be differentiated by type of treatment facility or system, size of operation, and kind of effluent treated to determine how cost varies as these factors change. Costs should also be determined for, and related to, separate categories under investment and operation in order to provide some economy efficiency criteria for waste treatment.

Research is needed on add-on values of starch and the synthetic resins for each of the yarns and fabrics on which they are considered substitutable. These data should be differentiated by type of fiber, ratio of blend, kind of fabric, yarn size and count, and machine speeds.

Research is also needed to provide a comprehensive cost analysis of starch and the synthetic resins in warp sizing. This should include actual prices paid for different kinds of starch and synthetic materials. More important, differences in operation, operation performance, and maintenance need to be determined precisely and in such a way that their effects on cost can be determined. A precise evaluation or rating of starches and the synthetic resins in sizing a representative number of fibers and fabrics would aid in making the cost analysis.

More knowledge is needed on the structure of the textile industry, particularly on variations in the size of plants as measured in terms of kind and quantity of output and processing practices.

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APPENDIX

Table 9.--Recommended sizing agents and pickups

Fiber	Form	Sizing agent	Desired pickup
			Percent
Cotton	Staple	Starch, CMC	15
Wool	Staple	Starch	25
Silk	Filament	Proteins	4-6
Rayon	Staple	Starch	15
	Filament	Starch	3-5
Acetate	Staple	Styrene maleic copolymer	15-20
	Filament	Styrene maleic copolymer	2-4
Triacetate	Staple	Polyvinyl alcohol	15-20
	Filament	Polyvinyl alcohol	2-4
Nylon	Staple	Polyvinyl alcohol	15-20
		Polyacrylic acid	
		Modified starches	
	Filament	(Same as staple)	3-6
Polyester	Staple	Polyvinyl alcohol	10-20
		Polyacrylic acids	
	Filament	(Same as staple)	4-6
Acrylics	Staple	Starch and polyvinyl alcohol	12-18
	Filament	Starch and polyvinyl alcohol	4-6
Olefins	Staple	Polyvinyl alcohol plus gums	10-20
	Filament	Proprietary	2-6
Glass	Filament	Proprietary	2-4

Reproduced from Dean A. Bixler (7, p. 28).

Table 10.--Typical formulas for sizing filament yarns

Fiber	Fabric	Size formula
Acetate	Taffetas various deniers	40-60 lb. maleic-styrene copolymer, 100% FINISH: 100 gal. Overwax: 0.5%
Arnel	Taffeta 3.0 oz/sq yd 75 den bright	22.5 lb. low viscosity PVA 22.5 lb. high viscosity PVA 5.0-7.5 lb. penetrant FINISH: 100 gal.
Arnel	Heavy sharkskin 7.4 oz/sq yd 300 den dull	25 lb. low viscosity PVA 25 lb. high viscosity PVA 7.0-7.5 lb. penetrant FINISH: 100 gal.
Dacron	Marquisette 2,200 ends 70/34/16 bright 48 x 32	65 lb. acrylic copolymer, sodium salt, 30% 92 gal. water FINISH: 100 gal.
Fortrel	Plain weave 40 den, 12 tpi 106 x 62	275 lb. acrylic copolymer, sodium salt, 30% 12 lb. wax emulsion, 45% FINISH: 100 gal.
Nylon	For 50, 70, and 100 den producer twist when sizing by Chemsize method	400 lb. polyacrylic acid, 25% 8 lb. emulsifiable oil FINISH: 100 gal.
Nylon	70 den, 2-ply Stretch nylon	96 lb. polyacrylic acid, 25% FINISH: 100 gal. Overwax: light overwax recommended
Polypropylene	165 to 210 den plain weave 52 x 45	300 lb. polyoxy copolymer 30% FINISH: 100 gal.

Reproduced from Carl R. Blemenstein (8, p. 60).

Table 11.--Typical formulas for sizing spun yarns

Fiber	Fabric	Size formula
Acetate	100% spun High sley	100 lb. starch ether gum, high substitution, low viscosity 15 lb. acrylic copolymer, sodium salt, 30% 6 lb. size wax FINISH: 90 gal.
Acrilan	100% spun blanket 16/1 yarns	260 lb. starch ether gum, medium substitution, low viscosity 40 lb. acrylic copolymer sodium salt, 30% 18 lb. size wax FINISH: 217 gal.
Arnel	100% spun Oxford 15/1 yarns	120 lb. starch ether gum, medium substitution, low viscosity 20 lb. PVA, low viscosity FINISH: 100 gal. Overwax: water dispersible type
Avril	50% Avril 50% cotton Print cloth 78 x 78 3,162 ends, 41" 30/1 warp 26/1 filling	100 lb. starch ether gum, high substitution, moderate viscosity 10 lb. emulsified fat-gum size compound, 40% 5 lb. size wax FINISH: 143 gal.
Avril	50% Avril 50% Fortrel broadcloth 95 x 60 4,798 ends Avril: 1.5 den. 1-3/16" staple Fortrel: 1.5 den. 1.5 staple, semi-dull	300 lb. starch acetate gum, low viscosity 54 lb. acrylic copolymer, sodium salt, 30% 21 lb. size wax FINISH: 220 gal.
Creslan	100% spun	300 lb. starch ether gum, high substitution, moderate viscosity 60 lb. acrylic copolymer sodium salt, 30% 18 lb. size wax FINISH: 150 gal.

cont'd.--

Table 11.--Typical formulas for sizing spun yarns (cont'd.)

Fiber	Fabric	Size formula
Dacron	65% Dacron 35% Pima cotton shirting 128 x 56 plain 5,980 ends 30s	300 lb. starch ether gum, moderate sbustitution, moderate viscosity 51 lb. acrylic copolymer, sodium salt, 30% 21 lb. size wax FINISH: 175 gal.
Dacron	Dacron-worsted suiting 32/1 and 20/1	460 lb. starch ether gum, moderate substitution, low viscosity 75 lb. acrylic copolymer, sodium salt, 30% 36 lb. size wax FINISH: 210 gal.
Dacron	65% Dacron 35% cotton poplin 128 x 56 5,980 ends, 30s Dacron: 1.5 den Cotton: Pima	300 lb. starch ether gum, moderate substitution, low viscosity 51 lb. acrylic copolymer, sodium salt, 30% 18 lb. size wax FINISH: 155 gal.
Fortrel	50% Fortrel 50% cotton poplin 5,828 ends, 25s	300 lb. starch ether gum, moderate substitution, low viscosity 51 lb. acrylic copolymer, sodium salt, 30% 22 lb. size wax FINISH: 200 gal.
Fortrel	100% Fortrel plain weave 106 x 62 Warp filament 40 den. 12 tpi Fill: Spun, 30s	275 lb. acrylic copolymer, sodium salt, 25% 12 lb. emulsifiable wax lubricant, 45% FINISH: 100 gal.
Kodel	50% Kodel 50% cotton Plain weave 116 x 58 4,770 ends, 41" 78 x 84 3,198 ends, 41" 32s warp Kodel: 1.5 den, 1.25" staple	300 lb. starch ether gum, moderate substitution, low viscosity 60 lb. acrylic copolymer, sodium salt, 30% 18 lb. size wax FINISH: 175 gal. (Sizeometer)

cont'd.--

Table 11.--Typical formulas for sizing spun yarns (cont'd.)

Fiber	Fabric	Size formula
Nylon	25% nylon 75% cotton Type IV twill 108 x 56 4,769 ends 14's yarn	245 lb. 40 fluidity corn starch 36 lb. acrylic copolymer, sodium salt, 40% 15 lb. emulsifiable wax compound 40% 8 lb. size wax FINISH: 200 gal.
Polypropylene	100% spun 2/2 R H twill 64 x 49 3,852 ends + 24 13/2 ply selvage polypropylene: 3.0 den. 1.5" staple	130 lb. starch ether gum, moderate substitution, moderate viscosity 100 lb. starch ether gum, moderate substitution, low viscosity 55 lb. acrylic copolymer, sodium salt, 40% 12 lb. size wax FINISH: 110 gal.
Viscose	70% viscose 30% acetate Plain weave 80 x 54 3,827 ends 18s warp	100 lb. modified corn starch, moderate viscosity 2 lb. synthetic and natural gum blend, 50% 5 lb. size wax FINISH: 100 gal. Overwax: 0.3% water dispersible type
Vycron	50% Vycron 50% cotton poplin 108 x 52 5,500 ends 18s	300 lb. starch ether gum, moderate substitution, low viscosity 45 lb. acrylic copolymer, sodium salt, 30% 21 lb. size wax FINISH: 210 gal., 500 psi homogenized
Zantrel	25% Zantrel 25% nylon 50% cotton	235 lb. pearl starch 40 lb. acrylic copolymer, sodium salt, 30% 20 lb. emulsified waxes 40% 5 lb. size wax 1 enxyme tablet (for thinning) FINISH: 207 gal. (Sizeometer)
	50% Zantrel 50% cotton broadcloth 108 x 59 5,216 ends 30s	200 lb. starch ether gum, high substitution, moderate viscosity 25 lb. acrylic copolymer, sodium salt, 30% 10 lb. size wax FINISH: 190 gal.

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